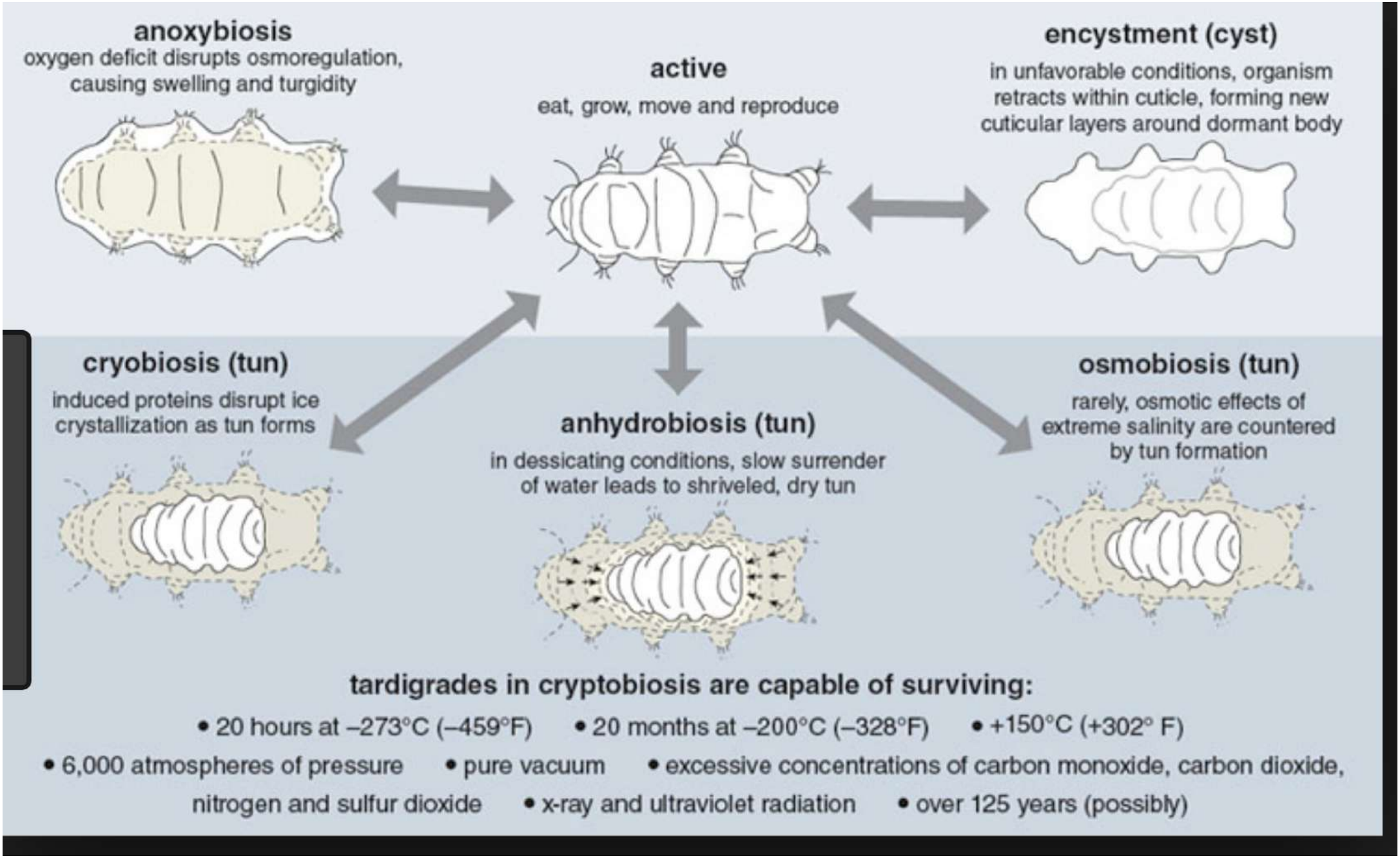
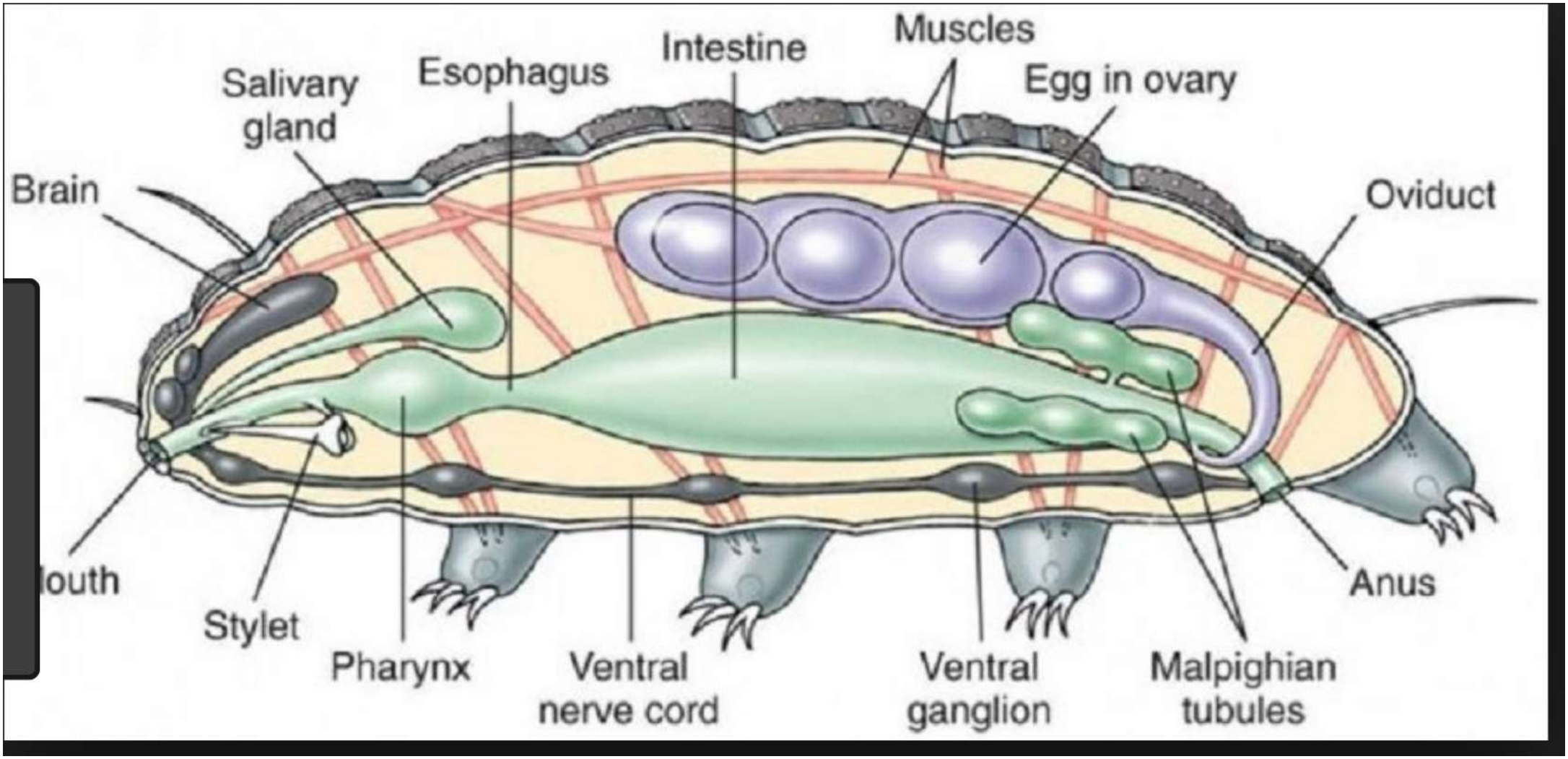
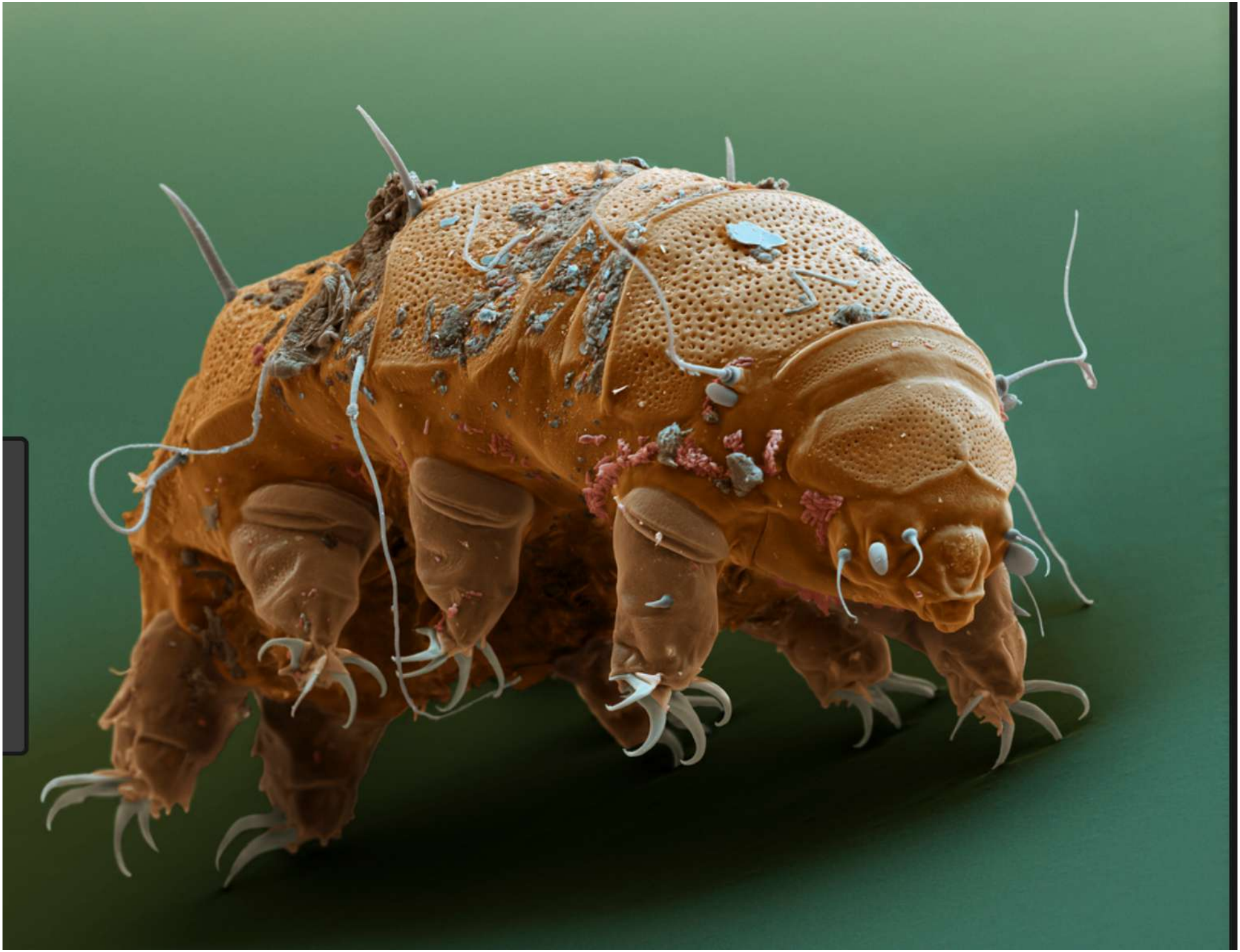

anoxybiosis
oxygen deficit disrupts osmoregulation, causing swelling and turgidity
active
eat, grow, move and reproduce
encystment (cyst)
in unfavorable conditions, organism retracts within cuticle, forming new cuticular layers around dormant body
cryobiosis (tun)
induced proteins disrupt ice crystallization as tun forms
anhydrobiosis (tun)
in dessicating conditions, slow surrender of water leads to shriveled, dry tun
osmobiosis (tun)
rarely, osmotic effects of extreme salinity are countered by tun formation
tardigrades in cryptobiosis are capable of surviving:
• 20 hours at –273°C (–459°F) • 20 months at –200°C (–328°F) • +150°C (+302° F)
• 6,000 atmospheres of pressure • pure vacuum • excessive concentrations of carbon monoxide, carbon dioxide, nitrogen and sulfur dioxide • x-ray and ultraviolet radiation • over 125 years (possibly)

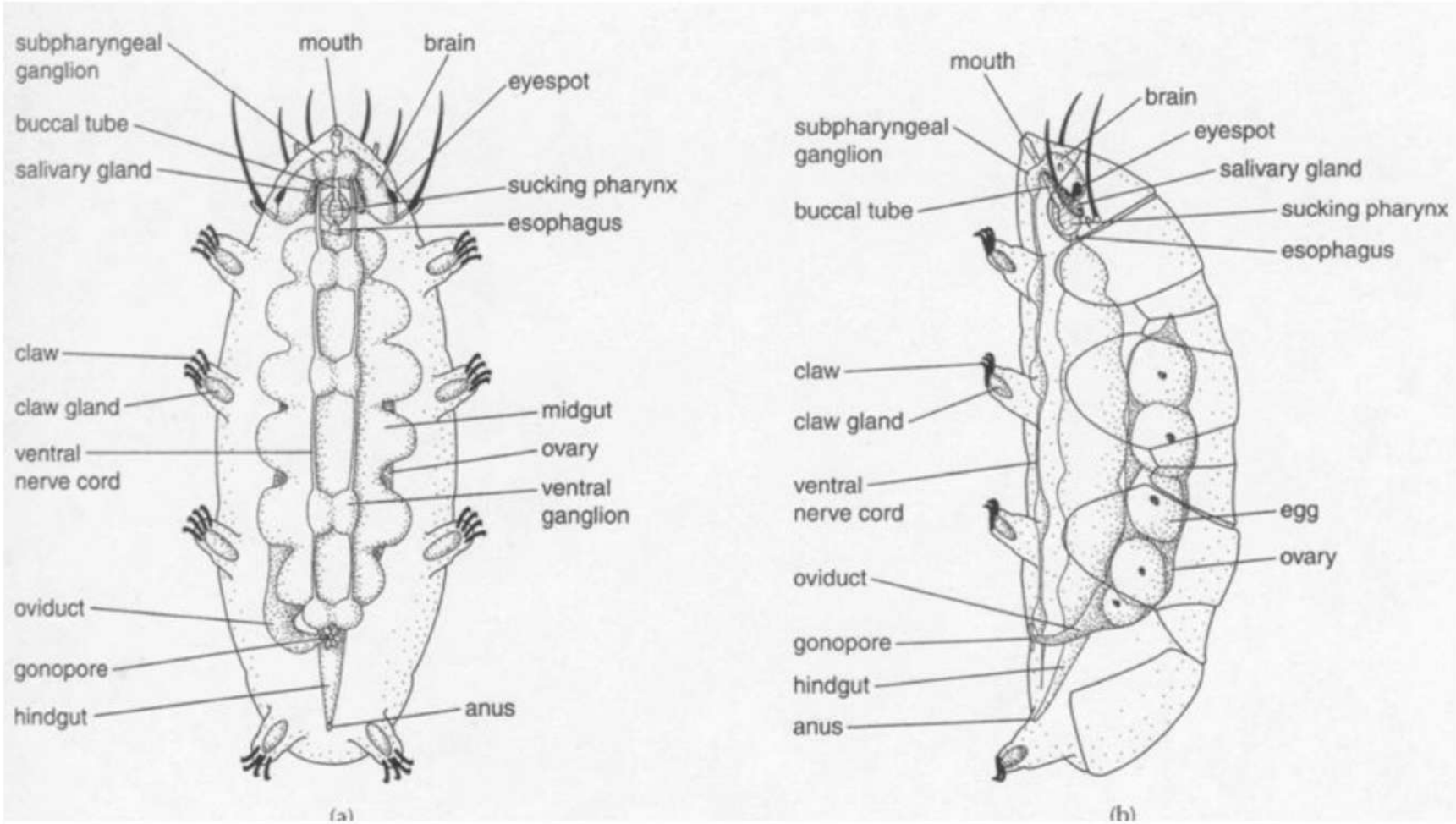

© W.P. Armstrong 2011


Muscles
Intestine
Esophagus
Salivary gland
Egg in ovary
Brain
Oviduct
Mouth
Stylet
Pharynx
Ventral nerve cord
Ventral ganglion
Malpighian tubules
Anus



Phylum Tardigrada

- nervous system similar to arthropods
  - paired ventral nerve cord




This animal came back to life after being frozen for more than 30 years.
SUBSCRIBE
0:02 / 0:48
MANAGED TO HAVE OFFSPRING

Reference:

Facts About Tardigrades

By Alina Bradford, Live Science Contributor | July 14, 2017 09:10am ET

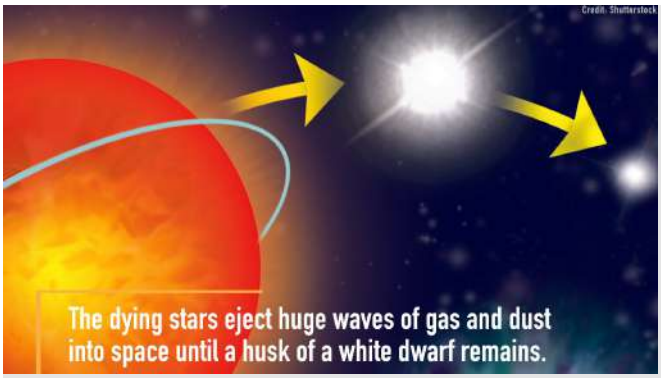
Diane Nelson, a Tardigrade researcher who works in Great Smoky Mountains National Park, used a scanning microscope to take this 3-D image of a Tardigrade.

Credit: NPS/Diane Nelson

Tardigrade is a phylum, a high-level scientific category of animal. (Humans belong in the Chordate phylum — animals with spinal cords.) There are over 1,000 known species within Tardigrade, according to Integrated Taxonomic Information System (ITIS).

Size

These creatures look like the hookah-smoking caterpillar from "Alice in Wonderland." They can range from 0.05 millimeters to 1.2 mm (0.002 to 0.05 inches) long, but they usually don't get any bigger than 1 mm (0.04 inches) long.



Habitat

Water bears can live just about anywhere. They prefer to live in sediment at the bottom of a lake, on moist pieces of moss or other wet environments. They can survive a wide range of temperatures and situations.

Research has found that tardigrades can withstand environments as cold as minus 328 degrees Fahrenheit (minus 200 Celsius) or highs of more than 300 degrees F (148.9 C), according to Smithsonian magazine. They can also survive radiation, boiling liquids, massive amounts of pressure of up to six times the pressure of the deepest part of the ocean and even the vacuum of space without any protection. A 2008 study published in the journal Current Biology found that some species of tardigrade could survive 10 days at low Earth orbit while being exposed to a space vacuum and radiation.

likely wipe out humans, the researchers found little tardigrades would survive most of them, they reported in a study published online July 14, 2017, in the journal Scientific Reports.

"To our surprise, we found that although nearby supernovas or large asteroid impacts would be catastrophic for people, tardigrades could be unaffected," David Sloan, a co-author of the new study and researcher at Oxford, said in a statement. "Therefore, it seems that life, once it gets going, is hard to wipe out entirely. Huge numbers of species, or even entire genera may become extinct, but life as a whole will go on."

Habits

Tardigrades were discovered by a German pastor, Johann August Ephraim Goeze, in 1773. He named them Tardigrada, which means "slow stepper." In 1776, Italian clergyman and biologist Lazzaro Spallanzani discovered that water bears survive extreme conditions by making a transformation.

In many conditions, they survive by going into an almost death-like state called cryptobiosis. They curl into a dehydrated ball, called a tun, by retracting their head and legs. If reintroduced to water, the tardigrade can come back to life in just a few hours.

While in cryptobiosis, tardigrades' metabolic activity gets as low as 0.01 percent of normal levels, and their organs are protected by a sugary gel called trehalose. They also seem to make a large amount of antioxidants, which may be another way to protect vital organs. Water bears also produce a protein that protects their DNA from radiation damage, according to research by the University of Tokyo.

In cold temperatures, they form into a special tun that prevents the growth of ice crystals.

They also have another defense for when they are in water. When the water they live in is low on oxygen, they will stretch out and allow their metabolic rate to reduce. In this state, their muscles absorb oxygen and water well enough that they can survive.

In 2016, scientists revived two tuns and an egg that had been in cryptobiosis for more than 30 years. The experiment was reported in the journal Cryobiology.

Reports from an experiment in 1948 claim that a tun over 120 years old had been revived, but this research has never been duplicated, according to the BBC.

Diet

Tardigrades reproduce through sexual and asexual reproduction, depending on the species. They lay one to 30 eggs at a time. During sexual reproduction, the female will lay the eggs and the males will fertilize them. In asexual reproduction, the female will lay the eggs and then they will develop without fertilization.

Classification/taxonomy

Here is the classification for tardigrades, according to ITIS:

Kingdom: Animalia
Subkingdom: Bilateria
Infrakingdom: Protostomia
Superphylum: Ecdysozoa
Phylum: Tardigrada

The Tardigrade phylum branches out into:

- 3 classes
- 5 orders
- 20 families
- 15 subfamilies
- 105 genera
- 4 subgenera
- 1,018 species
- 67 subspecies

Conservation status

Tardigrades have not been evaluated by the International Union for Conservation of Nature. They are also not on any other endangered list and have survived five mass extinctions over the course of around a half a billion years, according to National Geographic.

Other facts

The water bear's mouth can telescope outward to reveal sharp teeth that are used to grab onto food.

WIKIPEDIA

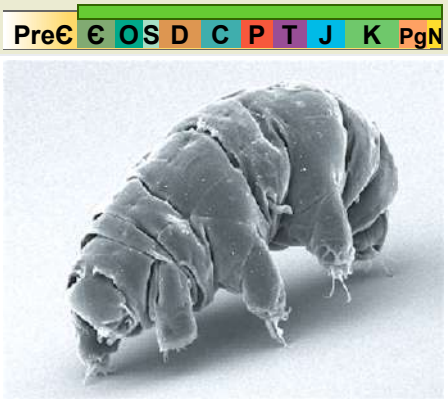
Tardigrade

Tardigrades (/ˈtɑːrdɪˌɡreɪd/; also known colloquially as **water bears**, or **moss piglets**)[2][3][4][5] are a phylum of water-dwelling, eight-legged, segmented micro-animals.[2][6] They were first described by the German zoologist Johann August Ephraim Goeze in 1773, who gave them the name of "little water bears". The name ***Tardigrada*** (meaning "slow steppers") was given in 1777 by the Italian biologist Lazzaro Spallanzani.[7] They have been found everywhere: from mountaintops to the deep sea and mud volcanoes;[8] from tropical rain forests to the Antarctic.[9] Tardigrades are among the most resilient known animals,[10][11] with individual species able to survive extreme conditions that would be rapidly fatal to nearly all other known life forms, such as exposure to extreme temperatures, extreme pressures (both high and low), air deprivation, radiation, dehydration, and starvation. Tardigrades have even survived exposure to outer space.[12][13] About 1,150 known species[14][15] form the phylum Tardigrada, a part of the superphylum Ecdysozoa. The group includes fossils dating from 530 million years ago, in the Cambrian period.[16]

Usually, tardigrades are about 0.5 mm (0.02 in) long when they are fully grown.[2] They are short and plump, with four pairs of legs, each ending in claws (usually four to eight) or sucking disks.[2][17] Tardigrades are prevalent in mosses and lichens and feed on plant cells, algae, and small invertebrates. When collected, they may be viewed under a very low-power microscope, making them accessible to students and amateur scientists.[18]

Tardigrades

Temporal range: Cambrian–Recent[1]



Milnesium tardigradum

Scientific classification

Kingdom:	Animalia
(unranked):	Tactopoda
Phylum:	**Tardigrada** Spallanzani, 1777

Classes

- Eutardigrada
- Heterotardigrada
- Mesotardigrada

Contents

Description

Johann August Ephraim Goeze originally named the tardigrade *kleiner Wasserbär*, meaning "little water bear" in German (today, they are often referred to in German as *Bärtierchen* or "little bear animal"). The name *Tardigradum* means "slow walker" and was given by Lazzaro Spallanzani in 1776.[19] The name "water bear" comes from the way they walk, reminiscent of a bear's gait. The biggest adults may reach a body length of 1.5 mm (0.059 in), the smallest below 0.1 mm. Newly hatched tardigrades may be smaller than 0.05 mm.

Johann August Ephraim Goeze

Habitat

Tardigrades are often found on lichens and mosses. Other environments are dunes, beaches, soil, and marine or freshwater sediments, where they may occur quite frequently (up to 25,000 animals per litre). Tardigrades, in the case of *Echiniscoides wyethi*,[20] may be found on barnacles.[21] Tardigrades can be often found by soaking a piece of moss in water.[22]

SEM image of *Hypsibius dujardini*

Anatomy and morphology

Lazzaro Spallanzani

Tardigrades have barrel-shaped bodies with four pairs of stubby legs. Most range from 0.3 to 0.5 mm (0.012 to 0.020 in) in length, although the largest species may reach 1.2 mm (0.047 in). The body consists of a head, three body segments each with a pair of legs, and a caudal segment with a fourth pair of legs. The legs are without joints, while the feet have four to eight claws each. The cuticle contains chitin and protein and is moulted periodically. The first three pairs of legs are directed downward along the sides, and are the primary means of locomotion, while the fourth pair is directed backward on the last segment of the trunk and is used primarily for grasping the substrate.[23]

Tardigrades lack several Hox genes and a large intermediate region of the body axis. In insects, this corresponds to the entire thorax and the abdomen. Practically the whole body, except for the last pair of legs, is made up of just the segments that are homologous to the head region in arthropods.[24]

All adult tardigrades of the same species have the same quantity of cells (see eutely). Some species have as many as 40,000 cells in each adult, while others have far fewer.[25][26]

The body cavity consists of a haemocoel, but the only place where a true coelom can be found is around the gonad. No respiratory organs are found, with gas exchange able to occur across the entirety of the body. Some tardigrades have three tubular glands associated with the rectum; these may be excretory organs similar to the Malpighian tubules of arthropods,

although the details remain unclear.[27] Also nephridia are absent.[28]

The tubular mouth is armed with stylets, which are used to pierce the plant cells, algae, or small invertebrates on which the tardigrades feed, releasing the body fluids or cell contents. The mouth opens into a triradiate, muscular, sucking pharynx. The stylets are lost when the animal molts, and a new pair is secreted from a pair of glands that lie on either side of the mouth. The pharynx connects to a short esophagus, and then to an intestine that occupies much of the length of the body, which is the main site of digestion. The intestine opens, via a short rectum, to an anus located at the terminal end of the body. Some species only defecate when they molt, leaving the feces behind with the shed cuticle.[27]

The brain develops in a bilaterally symmetric pattern.[29] The brain includes multiple lobes, mostly consisting of three bilaterally paired clusters of neurons.[30] The brain is attached to a large ganglion below the esophagus, from which a double ventral nerve cord runs the length of the body. The cord possesses one ganglion per segment, each of which produces lateral nerve fibres that run into the limbs. Many species possess a pair of rhabdomeric pigment-cup eyes, and numerous sensory bristles are on the head and body.[31]

Tardigrades all possess a buccopharyngeal apparatus (swallowing device made of muscles and spines that activates an inner jaw and begins digestion and movement along the throat and intestine[32]) which, along with the claws, is used to differentiate among species.

Reproduction

Although some species are parthenogenic, both males and females are usually present, each with a single gonad located above the intestine. Two ducts run from the testes in males, opening through a single pore in front of the anus. In contrast, females have a single duct opening either just above the anus or directly into the rectum, which thus forms a cloaca.[27]

Shed cuticle of female tardigrade, containing eggs.

Tardigrades are oviparous, and fertilization is usually external. Mating occurs during the molt with the eggs being laid inside the shed cuticle of the female and then covered with sperm. A few species have internal fertilization, with mating occurring before the female fully sheds her cuticle. In most cases, the eggs are left inside the shed cuticle to develop, but some species attach them to nearby substrate.[27]

The eggs hatch after no more than 14 days, with the young already possessing their full complement of adult cells. Growth to the adult size, therefore, occurs by enlargement of the individual cells (hypertrophy), rather than by cell division. Tardigrades may molt up to 12 times.[27]

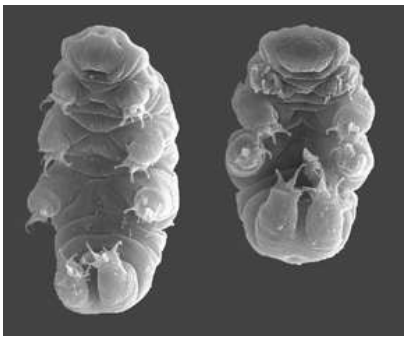
Ecology and life history

Most tardigrades are phytophagous (plant eaters) or bacteriophagous (bacteria eaters), but some are carnivorous to the extent of eating other smaller species of tardigrades (e.g., *Milnesium tardigradum*).[33][34]

Tardigrades share morphological characteristics with many species that differ largely by class. Biologists have a difficult time finding verification among tardigrade species because of this relationship. These animals are most closely related to the early evolution of arthropods.[35] Tardigrade fossils go as far back as the Cretaceous period in North America. This specific species is considered cosmopolitan and can be located in regions all over the world. The eggs and cysts of tardigrades are so resistant to other dangers that they are carried great distances, on the feet of other animals, to a different location.[17]

The lifespan of tardigrades range from 3–4 months for some species, up to 2 years for other species, not counting the time they spend in dormant states.[36]

Physiology



Hypsibius dujardini imaged with a scanning electron microscope

Scientists have reported tardigrades in hot springs, on top of the Himalayas[37] (6,000 m; 20,000 ft, above sea level) to the deep sea (−4,000 m; −13,000 ft) and from the polar regions to the equator, under layers of solid ice, and in ocean sediments. Many species can be found in milder environments such as lakes, ponds, and meadows, while others can be found in stone walls and roofs. Tardigrades are most common in moist environments, but can stay active wherever they can retain at least some moisture.

Tardigrades are considered to be able to survive even complete global mass extinction events due to astrophysical events, such as gamma-ray bursts, or large meteorite impacts.[10][11] Some of them can withstand extremely cold temperatures down to 1 K (−458 °F; −272 °C) (close to absolute zero), while others can withstand extremely hot temperatures up to 420 K (300 °F; 150 °C)[38] for several minutes, pressures about six times greater than those found in the deepest ocean trenches, ionizing radiation at doses hundreds of times higher than the lethal dose for a human, and the vacuum of outer space.[39] They can go without food or water for more than 30 years, drying out to the point where they are 3% or less water, only to rehydrate, forage, and reproduce.[3][40][41][42][43] Tardigrades that live in harsh conditions undergo an annual process of cyclomorphosis, allowing for survival in sub-zero temperatures.[44]

They are not considered extremophilic because they are not adapted to exploit these conditions, only to endure them. This means that their chances of dying increase the longer they are exposed to the extreme environments,[7] whereas true extremophiles thrive in a physically or geochemically extreme environment that would harm most other organisms.[3][45][46]

Tardigrades are one of the few groups of species that are capable of suspending their metabolism (see cryptobiosis). Many species of tardigrade can survive in a dehydrated state up to five years, or in exceptional cases longer.[47][48] Depending on the environment, they may enter this state via anhydrobiosis, cryobiosis, osmobiosis, or anoxybiosis. While in this state, their metabolism lowers to less than 0.01% of normal and their water content can drop to 1% of normal.[39] Their ability to remain desiccated for such long periods was thought to be largely dependent on the high levels of the nonreducing sugar trehalose, which protects their membranes, although recent research suggests that tardigrades have a unique type of disordered protein that serves a similar purpose: It replaces water in the cells and adopts a glassy, vitrified state when the animals dry out.[49] Their DNA is further protected from radiation by a protein called "dsup" (short for *damage suppressor*).[50][51] In this cryptobiotic state, the tardigrade is known as a tun.[52]

Tardigrades are able to survive in extreme environments that would kill almost any other animal. Extremes at which tardigrades can survive include those of:

- Temperature – tardigrades can survive:
  - A few minutes at 151 °C (304 °F)[53]
  - 30 years at −20 °C (−4 °F)[54]
  - A few days at −200 °C (−328 °F; 73 K)[53]
  - A few minutes at −272 °C (−458 °F; 1 K)[55]

- Pressure – they can withstand the extremely low pressure of a vacuum and also very high pressures, more than 1,200 times atmospheric pressure. Tardigrades can survive the vacuum of open space and solar radiation combined for at least 10 days.[56] Some species can also withstand pressure of 6,000 atmospheres, which is nearly six times the pressure of water in the deepest ocean trench, the Mariana Trench.[25]
- Dehydration – the longest that living tardigrades have been shown to survive in a dry state is nearly 10 years,[41][42] although there is one report of leg movement, not generally considered "survival",[57] in a 120-year-old specimen from dried moss.[58] When exposed to extremely low temperatures, their body composition goes from 85% water to only 3%. As water expands upon freezing, dehydration ensures the tardigrades do not get ripped apart by the freezing ice.[59]
- Radiation – tardigrades can withstand 1,000 times more radiation than other animals,[60] median lethal doses of 5,000 Gy (of gamma rays) and 6,200 Gy (of heavy ions) in hydrated animals (5 to 10 Gy could be fatal to a human).[61] The only explanation found in earlier experiments for this ability was that their lowered water state provides fewer reactants for ionizing radiation.[61] However, subsequent research found that tardigrades, when hydrated, still remain highly resistant to shortwave UV radiation in comparison to other animals, and that one factor for this is their ability to efficiently repair damage to their DNA resulting from that exposure.[62]

  > Irradiation of tardigrade eggs collected directly from a natural substrate (moss) showed a clear dose-related response, with a steep decline in hatchability at doses up to 4 kGy, above which no eggs hatched.[63] The eggs were more tolerant to radiation late in development. No eggs irradiated at the early developmental stage hatched, and only one egg at middle stage hatched, while eggs irradiated in the late stage hatched at a rate indistinguishable from controls.[63]

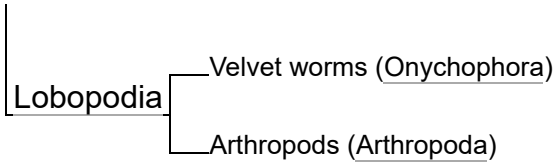
- Environmental toxins – tardigrades are reported to undergo chemobiosis, a cryptobiotic response to high levels of environmental toxins. However, as of 2001, these laboratory results have yet to be verified.[57][58]
- Outer space – tardigrades are the first known animal to survive in outer space. In September 2007, dehydrated tardigrades were taken into low Earth orbit on the FOTON-M3 mission carrying the BIOPAN astrobiology payload. For 10 days, groups of tardigrades were exposed to the hard vacuum of outer space, or vacuum and solar UV radiation.[3][64][65] After being rehydrated back on Earth, over 68% of the subjects protected from high-energy UV radiation revived within 30 minutes following rehydration, but subsequent mortality was high; many of these produced viable embryos.[56][66] In contrast, hydrated samples exposed to the combined effect of vacuum and full solar UV radiation had significantly reduced survival, with only three subjects of *Milnesium tardigradum* surviving.[56] In May 2011, Italian scientists sent tardigrades on board the International Space Station along with extremophiles on STS-134, the final flight of Space Shuttle *Endeavour*.[67][68][69] Their conclusion was that microgravity and cosmic radiation "did not significantly affect survival of tardigrades in flight, confirming that tardigrades represent a useful animal for space research."[70] In November 2011, they were among the organisms to be sent by the U.S.-based Planetary Society on the Russian Fobos-Grunt mission's Living Interplanetary Flight Experiment to Phobos; however, the launch failed. Tardigrades are one of the few groups to have survived Earth's five mass extinctions.[71]

Taxonomy

Scientists have conducted morphological and molecular studies to understand how tardigrades relate to other lineages of ecdysozoan animals. Two plausible placements have been proposed: tardigrades are either most closely related to Arthropoda ± Onychophora, or to nematodes. Evidence for the former is a common result of morphological studies; evidence of the latter is found in some molecular analyses.

The latter hypothesis has been rejected by recent microRNA and expressed sequence tag analyses.[72] Apparently, the grouping of tardigrades with nematodes found in a number of molecular studies is a long branch attraction artifact. Within the arthropod group (called panarthropoda and comprising onychophora, tardigrades and euarthropoda), three patterns of relationship are possible: tardigrades sister to onychophora plus arthropods (the lobopodia hypothesis); onychophora sister to tardigrades plus arthropods (the tactopoda hypothesis); and onychophora sister to tardigrades.[73] Recent analyses indicate that the panarthropoda group is monophyletic, and that tardigrades are a sister group of Lobopodia, the lineage consisting of arthropods and Onychophora.[72][74]

Panarthropoda
└── Water bears (Tardigrada)



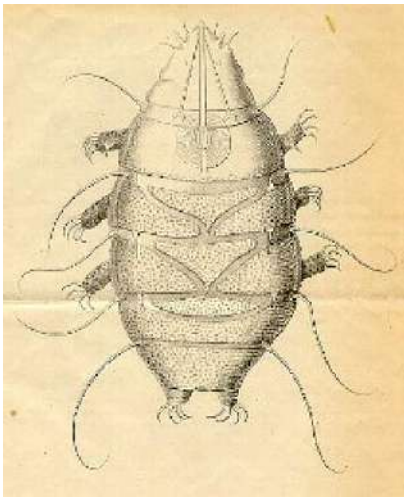


Illustration of *Echiniscus* sp. from 1861

The minute sizes of tardigrades and their membranous integuments make their fossilization both difficult to detect and highly unusual. The only known fossil specimens are those from mid-Cambrian deposits in Siberia and a few rare specimens from Cretaceous amber.[75]


Echiniscus

The Siberian tardigrade fossils differ from living tardigrades in several ways. They have three pairs of legs rather than four, they have a simplified head morphology, and they have no posterior head appendages, but they share with modern tardigrades their columnar cuticle construction.[1] Scientists think they represent a stem group of living tardigrades.[75]

Rare specimens in Cretaceous amber have been found in two North American locations. *Milnesium swolenskyi*, from New Jersey, is the older of the two; its claws and mouthparts are indistinguishable from the living *M. tardigradum*. The other specimens from amber are from western Canada, some 15–20 million years earlier than *M. swolenskyi*. One of the two specimens from Canada has been given its own genus and family, *Beorn leggi*, but it bears a strong resemblance to many living specimens in the family Hypsibiidae.[75][76]

Evolutionary history

There are multiple lines of evidence that tardigrades are secondarily miniaturised from a larger ancestor[77], probably a lobopodian and perhaps resembling *Aysheaia*, which many analyses place close to the divergence of the tardigrade lineage.[78][79]

An alternative hypotheses derives tactopoda from a grade encompassing dinocaridids and *Opabinia*.[80]

Genomes and genome sequencing

Tardigrade genomes vary in size, from about 75 to 800 megabase pairs of DNA.[81] *Hypsibius dujardini* has a compact genome of 100 megabase pairs[82] and a generation time of about two weeks; it can be cultured indefinitely and cryopreserved.[83]

The genome of *Ramazzottius varieornatus,* one of the most stress-tolerant species of Tardigrades, was sequenced by a team of researchers from the University of Tokyo in 2015. Analysis revealed less than 1.2% of its genes were the result of horizontal gene transfer. They also found evidence of a loss of gene pathways that are known to promote damage due to stress. This study also found a high expression of novel Tardigrade-unique proteins, including Damage suppressor (Dsup), which was shown to protect against DNA damage from X-ray radiation. The same team applied the Dsup protein to human cultured cells and found that it suppressed X-ray damage to the human cells by ≈40%.[51]

Ecological importance